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Fabrication and study of the characteristics of a portable cooling system

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ABSTRACT
This study aims at developing a thermoelectric cooler using the effect of plutene. One result obtained when operating the device at 12 volts is the low temperature inside the thermoelectric radiator to a degree of (1 °C), while the hot side temperature is (38 °C) and the efficiency obtained is (7).

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تصنيع ودراسة خصائص منظومة تبريد محمولة

حنين عبدالخالق ناجي، ياسين حميد محمود

قسم الفيزياء، كلية العلوم، جامعة تكريت، تكريت، العراق

الملخص

الهدف من هذا البحث هو تطوير مبرد كهروحراري باستخدام تأثير البلتير. إحدى النتائج التي تم الحصول عليها عند تشغيل الجهاز عند ١٢ فولت هي درجة الحرارة المنخفضة داخل المبرد الكهروحراري إلى درجة (1 °C) بينما كانت درجة الحرارة الجانبية الساخنة قيمتها (٣٨ °C) والكفاءة التي حصلنا عليها هي (٧).

الكلمات المفتاحية

مبرد كهروحراري ، حوض حراري، تأثير بلتيير ، نظام التبريد.

1. Introduction

Due to the recent circumstances of the coronavirus pandemic and the need to keep vaccines in a safe place through moving them from one place to another, a portable refrigerator has to be designed to be used for such purpose. Given the thermoelectric phenomenon, new thermoelectric devices have to be developed in order to increase their performance using new structures with low-dimensional materials. It is found that thermoelectric devices have great potential for many applications in different industries and fields. Thermoelectric refrigerants provide a very environmentally friendly and silent solution, and can be used in cars, homes and food industry [1]. Therefore, a thermoelectric cooling box that works on batteries is designed. The advanced electrical thermal cooling system has the potential to store and transport life-saving drugs and biological materials in areas where no electricity is available. Most importantly, there is a considerable possibility to develop materials specifically suitable for the purpose of thermoelectric (TE) cooling. Developing new ways to improve efficiency that meet changes in the basic manufacture of thermoelectric setting, such as the best heat transfer, miniaturization, etc., can greatly enhance the overall performance of thermoelectric refrigerators [2]. This is attributed to that the traditional refrigeration system is large in size and consumes a lot of electric power that leads to more gas being released into the environment. Compact electric thermal refrigerators are developed with consuming less electric energy that supports the use of renewable energy resources, such as solar, tidal and wind energy. A study on the thermoelectric refrigerator found that the temperature decreases by (10 ℃ and 12 ℃) degrees in the upper and lower chambers, respectively, within 10 minutes. This range for refrigerator performance can be greatly improved using efficient liquid cooling system to lower the hot side temperature to the lowest possible degree [3]. Solar energy is used to produce cooling at a lower temperature including refrigerated solar or photovoltaic (PV) system, absorbent cooling and solar mechanical systems. Among these systems, PV or solar thermal energy using thermoelectric technology, which is the most feasible and convenient means for portable systems regardless of place, can be connected as a freezer on wheels. Thus, the refrigerator is environmentally friendly with a small size, without fluorine pollution, as well as no moving parts in the system. Solar-powered refrigerators are usually used in off-grid locations where facilities that provide AC power are not available. They can be implemented regardless of several conditions to meet the future developments and to use the traditional sources in a wide possible way. Such refrigerators can be used worldwide, as they are efficient and economical in areas where there is no electricity and cooling is required [4]. Moreover, a solar-powered refrigerator is developed using the effect of Peltier and some cooling materials. Thermal cooling techniques have become popular because they are environmentally friendly and can be used in remote areas. The solar thermoelectric refrigerator is designed to maintain temperature range up to (10 ℃). Thermoelectric refrigerator has a large range of application in refrigeration, air conditioning, food conservation, medical services, etc. The solar thermoelectric refrigerator is required to protect the environment because it uses solar and electrical energy and is of benefit to people who live in high temperature areas [5]. In another study, a compact and movable refrigerator with no harm to the environment is designed mainly for keeping drugs under severe conditions. The thermoelectric unit (TEM) is used instead of the compressor so that it becomes portable and lightweight, and operates on the principle of the Peltier effect. The use of the Peltier effect is to establish heating and cooling sides and also to preserve effectiveness of refrigerator. It is found that the machine has great precision and full heat transfer capabilities while meeting the precision requirements. It can be used to cool small drinks, drinking water, medicines, etc. [6]. A small size refrigerator was designed in another study, which aimed to analyze the performance and factors of this refrigerator. The study found that the industrialization of a mini-fridge using a thermoelectric unit was successfully completed. The temperature in the freezer could be reduced from (28.5 ℃) to (13.6 °C). The study recommended conducting more research on the development of refrigerators using thermal electricity, especially for those which have the potential to obtain a highest performance coefficient [7].

2. The Theoretical Part

Thermoelectric System

It is an electric technology that is produced directly from heat. This technology of electric production is originally based on the SEPAC effect, which is a principle discovered by the scientist Thomas Sepac. Thermal electricity arises from the connection of two different semiconductor types at their end in an electrolytic circuit. When one of the ends of this connection is at a temperature different from the temperature of the second connection, a direct electric current is created in an electric circuit. The amount of power output in the electrical circuit depends mainly on the temperature difference between the conductor ends. In other words, increasing the heat at one end and reducing it at the other end will result in a higher amount of electric current [8].

Thompson Effect

In different materials, the SEPEC coefficient is not constant in temperature, so the spatial gradient in temperature can lead to a gradient in the SEPEC coefficient. If a current is pushed through this gradient, there will be a continuous version of the Peltier effect. Thompson's effect was predicted and then observed by Lord Kelvin in 1851, who described heating or cooling a current-bearing conductor with temperature gradient. Hence, if the current density is passed through a homogeneous conductor, Thompson's effect predicts the rate of q heat production per unit size [8].

Seebeck Effect

Seebeck effect refers to the conversion of heat directly into electricity at the intersection of different types of wires. It is named so according to the name of the German physicist Thomas Johan Sebek, who discovered it in 1821. In this regard, when the compass needle would be deflected by a closed ring of two different minerals attached to two places, with a temperature difference between the joints. This is because the electron power levels in each metal are shifted differently and the voltage difference between the intersections creates an electric current and thus a magnetic field around the wires. Seebeck did not realize that an electrical current is involved, so he called the phenomenon "thermomagnetic effect." Then, the Danish physicist Hans Christian Orsted corrected the direction and coined the term thermal energy. Seebeck effect is a classic example of electrical power (EMF) and leads to currents or measurable voltage in the same way as any other EMFs. Electrical forces modify OEM law by generating currents even in the absence of voltage differences [8].

Peltier Effect

A thermoelectric chiller (TCE), sometimes called a thermoelectric unit or Peltier chiller, is a semiconductor-based electronic component that acts as a small heat pump. By applying a low voltage Direct Current (DC) power source to the TCE unit, the heat will be transferred through the thermoelectric unit from side to side. So, one unit face will be cooled while the opposite face is heated simultaneously. It is important to note that this phenomenon can be reversed as a change in polarity (plus and minus) of the applied DC voltage moves heat in the opposite direction. Thus, a thermoelectric unit can be used for heating and cooling, making it highly suitable for precision temperature control applications.

By using the equations to find the values of Q_C , Q_H and total energy (P), the value of the COP power coefficient is found as follows [9]:

The heat absorbed by the cold side of the Peltier unit is taken by [9]:

$$Q_C = [\alpha I T_C - ½ I^2 R - K (T_H - T_C)] \dots\dots\dots\dots (1)$$

(-) an indication of heat rejection.

Heat rejected by the hot side of the Peltier unit is taken by using this equation:

$$Q_H = [\alpha I T_H - ½ I^2 R - K (T_H - T_C)] \dots\dots\dots\dots (2)$$

Seebeck Effect

Seebeck coefficient (α) and the thermal conductivity (K) of the Peltier unit depend on the materials used in TEC and machine engineering.

Where α = Seebeck coefficient (V/K)

I = System supplier current

Tc = Cool side temperature

TH = Hot side temperature

R = Electrical resistance (Ω)

K = Thermal conductivity (W/K)

QC = Heat absorbed by Peltier Unit (W)

QH = Heat rejected by Peltier Unit (W)

TEC1-12706

(Seebeck coefficient (α) = 0.02117 (V/K

Thermal conductivity (K) = 0.4995 K/W

Electrical Resistance (R) = 0.85 (Ω)

Total power supplied (P) to the Peltier unit is given in the following equation:

$$P = Q_H - Q_C \dots\dots\dots\dots (3)$$

Where P = Total energy supplied

COP Power Coefficient:

$$COP = \frac{Q_C}{\text{Energy Supplied}} \dots\dots\dots (4)$$

3. Experimental Work

A thermoelectric chiller (TE), the so-called thermoelectric unit or Peltier chiller, is an electronic element found in semiconductors that acts as a small heat pump. When a low voltage power source (DC) is applied to the TCE unit, heat will be transferred through the unit from side to side. Therefore, one unit face will be cooled, while the opposite face is heated simultaneously. It is important to note that this phenomenon can be reversed because the change in polar voltage (plus and minus) of applied voltage (DC) moves heat in the opposite direction. Thus, the thermoelectric unit can be used for heating and cooling, making it suitable for precision temperature control applications [9]. Peltier device is shown in figure (1), with the specifications listed in table (1).

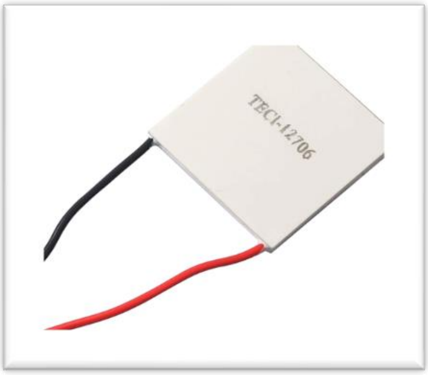

Figure (1): Peltier 12706 SE

Table (1): The specifications of Peltier

Type Peltier element	TEC (Thermoelectric cooler)
Design	Without silicone sealed
Max. Temperature	138°C
Max. Voltage	15.4V
Max. Current	6.4A
Resistance	27g
Qmax. @ Delta T=0	63W
Delta T max.	68°C
P-N Junction	127 couples
Material	Al2O3 (aluminum oxide)
Wire Size	18AWG
Wire length	150mm
Wire Insulation Material	Teflon
Weight	27g
Size	40x40x3.8mm
Manufacturer PN	TEC1-12706
Manufacturer	Hebei

Heat Sinks

Thermal dispenser of aluminum material with thickness of (2mm) dimensions (2.6x4 - 10) cm was used in this study. Figure (2) shows the heat sink used.

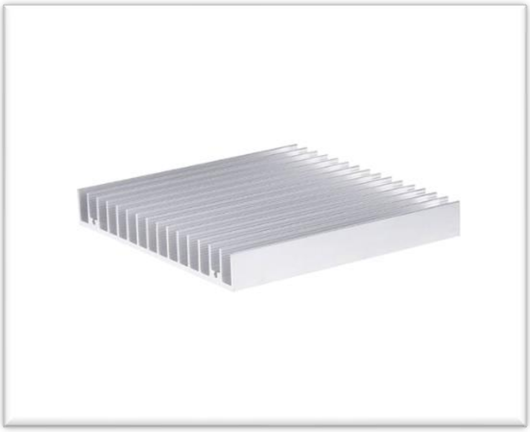

Figure (2): The heat sink

Fan

A (9 Cm) dimension fan was used and operated with 12V voltage and (0.18-0.23) (A) current, as shown in figure (3).

Figure (3): The fan

Quiet DC 12V Submersible Pump

Super quiet submerged water pump, shown in figure (4), was used and operated at (12V) with no high quality brush and characterized by having very long working life, low noise, submersible installation and fully waterproof, amphibious design, high quality and low consumption.

Figure (4): The pump

Water-cooled heat exchanger radiator

Water radiator, shown in figure (5), of aluminum with size (12cm) including thin chips of aluminum to increase cooling efficiency, was used in hydro cooling systems, such as the cooling and heating dispersion.

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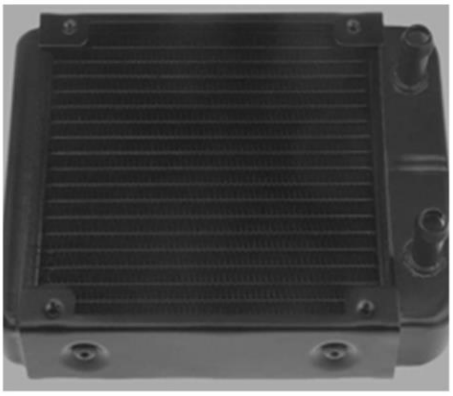

Figure (5): Radiator

The complete portable system is shown in figure (6).

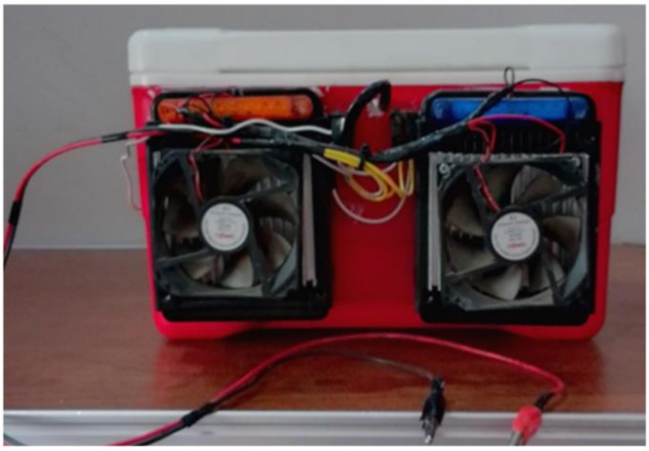

Figure (6): The cooling system

4. Results and discussion

When the electrical voltage was equipped (12 V) on the Peltier unit, the temperature began to drop from the cold side inside the system, as the temperature changed inside the cooling box (cooler). This is offset by an increase in temperatures from the other side of the Peltier. The heat then travelled to the rear heat dispersion in the way of conduction. The thermal dispersion absorbed the high heat of Peltier. This absorption helped small fans that were placed on the thermal dispersants and in turn drew the heat outwards. Then, the cold side moved to the sides of the refrigerator from its inside part. The process continued until the complete cooling of the cooler atmosphere was achieved. Then, the temperature dropped to (1 °C) within 10 minutes of ambient temperature, as shown in figure (7). This is consistent with the study of [10].

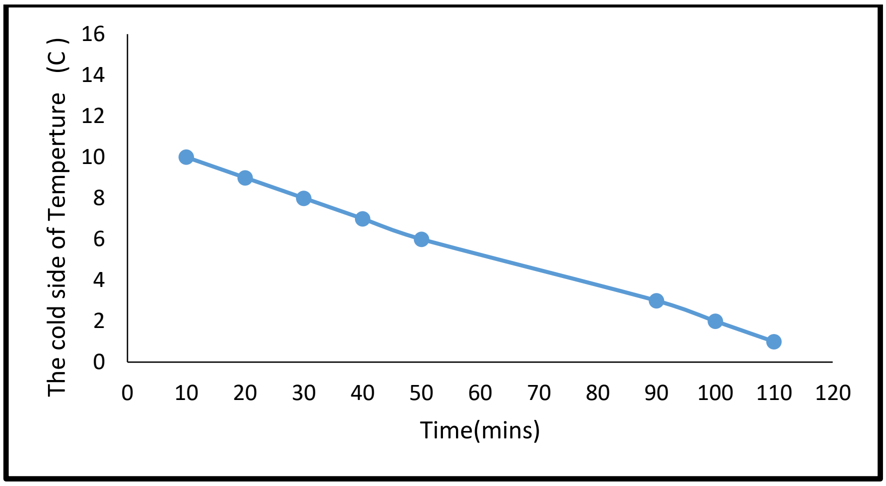

Figure (7): The relation between the cold side temperature and time

The temperature also began to rise from the hot side of the cooler outside. On the Peltier unit, the temperature began to drop from the cold side of the cooler inside as the temperature changed inside the cooling box (cooler). This is offset by an increase in temperatures from the other side of the Peltier unit. The heat then travelled to the rear heat dispersion in the way of conduction. The thermal dispersion absorbed the high heat of the Peltier. This absorption helped small fans that were placed on the thermal dispersants and in turn drew the heat outwards. Then, the cold side moved to the sides of the refrigerator from the inside. The process continued until the complete cooling of the cooler atmosphere was achieved. This temperature rise was within 10 minutes of ambient temperature, as shown in figure (8). This is consistent with the study of [11].

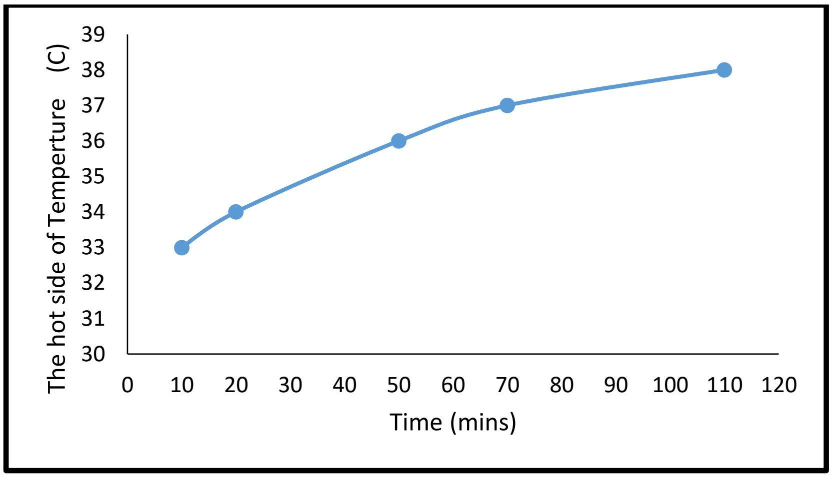

Figure (8): The relation between the hot side temperature and time

The change in the efficiency factor of the device has also been studied previously. When operated the device at (12 V), the efficiency coefficient began to decline. The performance factor of thermoelectric refrigerants is based on the efficiency of the hot and cool leak on the fan, as shown in figure (9). This is consistent with the study of [12].

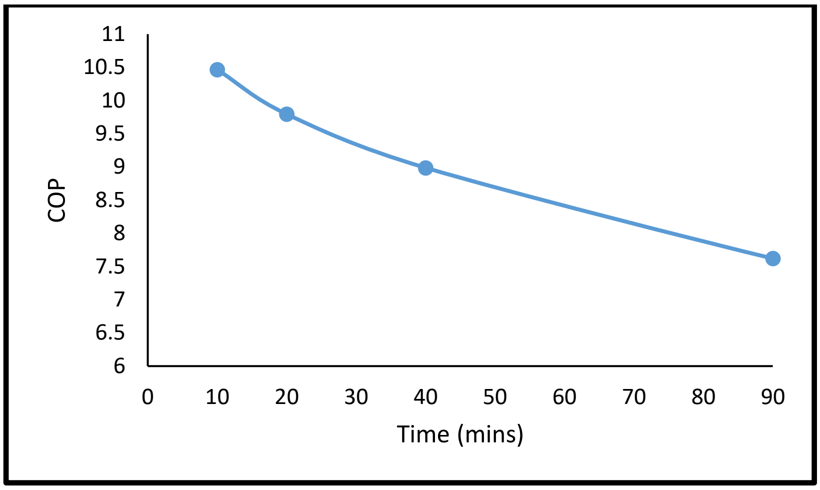

Figure (9): The relation between COP and time

Figure (10) shows the change in the efficiency factor of the device with the temperature difference. It was observed that the efficiency factor of the device when operating the device at (12 V) was decreased. This decrease increased as the difference in temperature was increased, due to the effectiveness of the Peltier and the efficiency of the shutdown process of the cooling box. This is compatible with the study of [13].

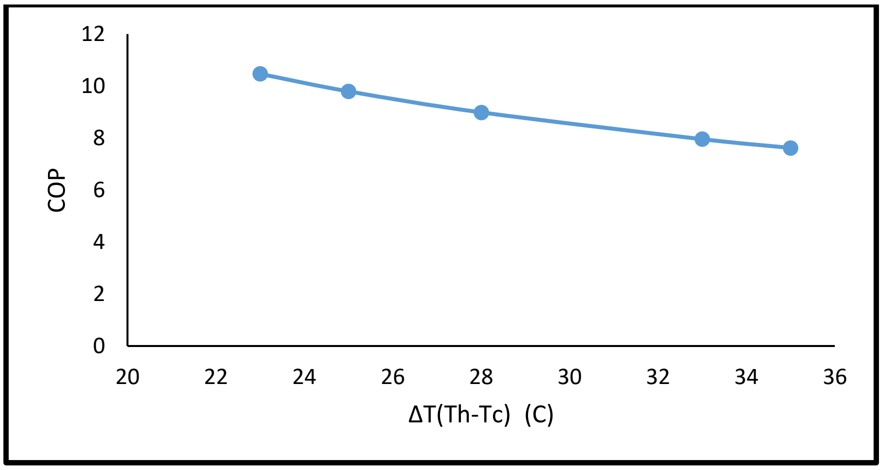

Figure (10): The power coefficient with difference in temperature

5. Conclusion

In the last two decades, interest in thermoelectric devices that easily provide heating and cooling has increased. This interest has encouraged the improvement of heat exchangers at either end of the Peltier units. This study showed the stability of exchanges working at 12v voltages to reduce the heat within the cooler box (refrigerator). The heat inside the cooler box fell within 10 minutes. There was a good temperature difference from the outer side, so the power factor increased during the same period. This happened because of the heat insulation efficiency as well as the heat leak and fan efficiency. The use of the Peltier in the portable refrigerator, specifically with small sizes, is effective.

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